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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—Bulletin No. 71.

D. E. SALMON, D. V. M., Chief of Bureau.

THE CAMEMBERT TYPE OF SOFT CHEESE IN THE UNITED STATES.

BY

H. W. CONN, CHARLES THOM, A. W. BOSWORTH,
W. A. STOCKING, JR., AND T. W. ISSAJEFF.



UNIVERSITY OF CALIFORNIA
LOS ANGELES

SEP 23 1952

WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1905.

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1905.

LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., March 23, 1905.

SIR: I have the honor to transmit herewith a manuscript entitled "The Camembert type of soft cheese in the United States," and to recommend its publication as a bulletin.

This paper represents the initiatory effort in a series of cooperative experiments which has been undertaken by the Dairy Division of this Bureau in conjunction with the Storrs (Conn.) Agricultural Experiment Station. The full scope and character of these experiments are explained in the introductory chapter on the next page.

It is anticipated this work will result in much benefit to a large class of our farmers and dairymen, who may thus find a new and highly remunerative outlet for their surplus milk supply.

Respectfully,

D. E. SALMON,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

INTRODUCTION.

The investigations in soft-cheese making were undertaken by the Storrs Agricultural Experiment Station with the hope that there might be developed a new industry especially adapted to New England conditions. The Camembert type of soft cheese seems especially adapted to home manufacture. The process of manufacture has, however, been held as a trade secret and no source of information has been available for those who may have desired to make this type of cheese. A series of preliminary studies was undertaken, and the results gave promise of a successful solution of the problems involved and demonstrated the value of the work.

The continuation of the investigations, however, involved a larger outlay than the means of the station would permit. Recognizing the wide value which would result should the experiments prove successful and a new industry be established, a cooperative agreement was entered into between the Storrs Agricultural Experiment Station and the Dairy Division of the Bureau of Animal Industry of the United States Department of Agriculture, Washington, D. C. Under the terms of this agreement a thorough study is to be made of the problems involved in the manufacture of some of the types of soft cheese which are so popular in Europe, but which have been manufactured in this country to a very limited extent only.

The Storrs Agricultural Experiment Station has furnished the necessary laboratories, apparatus, and curing rooms for conducting the experiments and has had the general planning of the work. The Dairy Division of the Bureau of Animal Industry has furnished three experts to assist in the work, namely, a mycologist, a chemist, and a practical cheese maker, and has provided for certain traveling expenses connected with the work. The organization of the actual working staff connected with these investigations is as follows:

H. W. Conn, bacteriologist of the Storrs Station, supervisor.

Charles Thom, cheese expert of the United States Department of Agriculture, mycologist.

A. W. Bosworth, cheese expert of the United States Department of Agriculture, chemist.

Theodore Issajeff, expert of the United States Department of Agriculture, cheesemaker.

W. A. Stocking, jr., assistant bacteriologist of the Storrs Station.

In addition to the foregoing, who have been actively engaged in the cheese investigations, credit is due to Dr. B. B. Turner, chemist of the Storrs Station and of the Connecticut Agricultural College, for valuable suggestions, and to Mr. W. M. Esten, laboratory assistant to Doctor Conn, for bacteriological determinations. The Connecticut Agricultural College has freely permitted the use of laboratories and apparatus for this work, without which we would have been seriously handicapped.

The work is now thoroughly organized and the investigations are being conducted with the following objects in view:

(1) To learn the details of the methods of manufacturing some of the soft cheeses.

(2) To learn more accurately the details of the process of ripening, and to determine the organic agents involved and their exact functions.

(3) To study the chemical composition of the ripened product, the changes involved in ripening, and their relation to food values and digestibility.

(4) To discover the difficulties connected with the manufacture of soft cheese and the ways of meeting them.

(5) To learn whether the manufacture of a first-class product is possible in the United States.

(6) To make public property of all useful and desirable information upon the subject of the manufacture of soft cheese.

This bulletin is necessarily preliminary in its nature, but it will be followed soon by others dealing specifically with the problems involved in soft-cheese making and how to solve them.

L. A. CLINTON,

Director Storrs Agricultural Experiment Station.

ED. H. WEBSTER,

Chief of Dairy Division, Bureau of Animal Industry.

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THE CAMEMBERT TYPE OF SOFT CHEESE IN THE UNITED STATES.

Introductory Paper.

By H. W. CONN, CHARLES THOM, A. W. BOSWORTH, W. A. STOCKING, Jr., and
T. W. ISSAJEFF.

SOFT CHEESES COMPARED WITH HARD CHEESES.

Hard cheeses have for a long time been well known in this country and have been manufactured by our dairymen in large quantities. Until recently little has been heard concerning another type of cheese properly called soft cheese. This latter type, although made from curdled milk, requires very different methods of manufacture, and when ready for the table is a totally different product. As the name indicates, the cheese is softer, frequently so soft as to be readily spread upon bread like butter. But in addition to this there are other striking differences between the soft and hard cheeses. The soft cheeses are smaller than most of the hard cheeses. They do not keep well. Above all, their flavor is quite different, being usually much stronger. It is a well-recognized fact that while cheese is a valuable food because of the large amount of protein it contains, nevertheless it owes its chief popularity to its flavor. Flavors are known to be physiologically necessary to the proper digestion and assimilation of foods. Hence the value of highly flavored foods that give relish to those coarser and less flavored can hardly be overestimated. The soft cheeses, with their strong flavors so thoroughly enjoyed by some people, have, therefore, a value decidedly their own.

The primary difference between the hard and soft cheeses is due to different methods of manipulation of the curdled milk. In the hard cheeses (Cheddar, Swiss, American, Edam, etc.) the milk is curdled rather rapidly and the curdled mass subsequently cut into small pieces to allow much of the whey to separate from the curd. Sometimes the curdled mass is heated still further to separate curd and whey. After this the curd is placed in frames and subjected to a high pressure that forces out more of the whey, leaving a very hard mass of tolerably dry curd. Such a curd ripens slowly and is not ready for market for some months, and even when perfectly ripe it preserves its form and never becomes very soft.

The soft cheeses—Camembert, Brie, Isigny, Limburger, Backstein, Neufchâtel, cream cheeses—although each is made in a special manner, all agree in one point, namely, the whey is never fully drained from them. The curdled milk is commonly ladeled into forms and allowed to drain naturally. Soft cheeses are not subjected to pressure or heat, and therefore contain a larger per cent of water at the start than the hard cheeses. As a consequence of their high water content and soft texture, they afford favorable conditions for the growth of various microorganisms, and enzyme action also occurs more readily than in hard cheeses. The action of these two groups of fermentation agents ripens the cheeses rapidly and develops high flavors. They are ready for the table in a few weeks instead of months, and when ripened have not only strong flavors but frequently very penetrating and more or less offensive odors, as in the well-known Limburger cheese. Because of the rapidity of the chemical changes going on in them, these cheeses are more perishable than the true hard cheeses. Their marketable period is very short. If placed upon the table at just the right period they are very appetizing. If insufficiently ripened they do not have the proper flavor or texture, and if even slightly overripened they rapidly show a tendency to decay and are soon ruined. To place them on the market in such a way that they reach the consumers' table at the proper stage of ripening is one of the difficult problems of the industry.

THE MARKET FOR SOFT CHEESES IN THE UNITED STATES.

The home of these cheeses is continental Europe. No part of Europe is without its types of soft cheese. There are several general types—like Limburger, Camembert, and Brie—that are widely distributed and made in different countries, and there are, in addition, many local varieties with a narrower reputation. From their centers of manufacture they are exported to various cheese-consuming countries, so that all of the chief types are generally found throughout Europe. Importations of soft cheeses to the United States have not been very large. The American market in the past has been almost monopolized by the hard cheeses, principally of the type of the English Cheddar. Americans have known little of the great variety of soft cheeses common in European markets, and there has consequently been very little call for them. Within the last generation a moderate demand for soft cheeses has been developed. This demand may be attributed partly to our increasing foreign population and to the desire of people of European birth for the types of cheese familiar to them at home. It is also partly due to the taste acquired by Americans who have traveled abroad, as well as to a growing appetite for them among others who have tried the

new delicacies. This has led to the importation of several varieties of soft cheese to satisfy a market which is increasing every year. This importation has reached about a million pounds, with a value of about \$150,000 per year.

There are many reasons why the total importations have not been greater. It is difficult to import the more delicate varieties in prime condition. Two weeks is the shortest period possible between leaving the factory and reaching the retail market in America. If fully and properly ripened before shipment these two weeks cover almost the entire marketable period of the cheese. To reach our market in condition for use at all they must be packed and shipped before they are in condition for the table. In practice some are shipped before they are half ripe or even when the ripening has just begun. The change of conditions and entire lack of care in transit makes the resulting cheeses which reach our markets of very uncertain quality. It is also difficult for the casual buyer to determine when the cheese is really ripe. These irregularities furnish good reasons why such importation is discouraging to dealer and to consumer alike.

On the other hand, these conditions have stimulated the production of certain soft cheeses in America. Particularly is this true of Limburger cheese, for which there is a large demand. It has been found not difficult to manufacture, and it is now made in this country in a number of places with a considerable degree of success. In response to a similar demand a considerable business has arisen in the manufacture of the forms sold in our markets, as Brie, Isigny, Wiener, lunch, miniature, etc., all of which, though sold under all sorts of trade names, have a common type of ripening. Although the details of form and making vary with the factory, the brand, and the season, these may be grouped together perhaps as the "American Brie" type. This American Brie type must not be confused with the French Brie type, for the latter is quite a different product. These American types have made for themselves a large market and may be regarded as a fairly well-established product. A preliminary study of their ripening process and the factories in which they are produced indicates, however, a very unsatisfactory condition. The ripening is so little understood and results are so uncertain that one maker admitted that after the cheese is made the flavor of the product is practically an accident over which he has no control. Some of the cheeses are ruined in the ripening and the factories that make them lose considerable of their product. It is evident, therefore, that the manufacture of the American type of these cheeses can hardly be regarded as a success until some means of controlling the ripening can be devised that shall reduce the failures and give a more uniform

product. Moreover, the American type, as before stated, is quite different from the French; it is stronger, has a more unpleasant odor, and a less delicate taste. The delicate tasting Brie and Camembert cheeses are mostly imported from France. Up to the present time their manufacture has been successful in but few places in America, and there is a general belief that their manufacture in this country is impossible.

Another indication of the growing popularity of soft cheeses is the large demand for the varieties sold under various brands as Neufchâtel and cream cheese. The basis for most of these is the common "Cottage" or "Dutch" cheese, and many of them are merely sweet or sour curd put in an attractive and appetizing form. The manufacture of these varieties is comparatively simple, with practically no danger of loss. They are sold and eaten when fresh. Further, they will yield a larger amount of salable cheese from the same quantity of milk than other varieties, and they bring prices almost as high as the best imported cheese. Very naturally these cheeses form the basis of a profitable industry. But here, too, we find that the common American product is different from the cheese in Europe going under the same name. The Neufchâtel cheese of Europe is a ripened cheese, but the cheese going by this name in the United States is usually unripened curd with an attractive wrapping. Some of these American products, however, are highly flavored and compete favorably with certain ripened types that are imported. All of them command a far higher price than the ordinary hard cheese.

It is certain, therefore, that there is an established and rapidly growing market for the best types of soft cheese. The profit in the manufacture of the hard types of cheese is exceedingly small, both to the factory and to the producer of milk, but the prices of the highest class of soft cheeses (40 cents or more per pound) are so much higher than the prices of the hard cheeses that the introduction of their manufacture should be a great benefit to the dairymen. The fact that soft cheese will not keep very long gives an especial advantage to the domestic over the foreign producers if the products can be made of equal merit. For such perishable products there is a great advantage in an intimate relation between the maker and the consumer. Factories near enough to a large city to supply the demand with cheese always ripened to exactly the prime condition should easily be able to control their home market if they can once control their product. It seems possible that there will be an advantage, nearer the small cities at least, in their production by individual dairymen who could dispose of their own product in a restricted market.

The great difficulty in the way of the successful development of the soft-cheese industry is in the difficulty of controlling the ripening

so as to produce a uniform product. Even in the localities where these cheeses are made in Europe their treatment seems to be purely by "rule-of-thumb" methods, handed down as the result of more or less successful experience, rather than by an accurate knowledge of the reasons for the various steps in the process. As a natural consequence, the results are to a large degree irregular, and utterly unexplained failures of many kinds are familiar occurrences. Recognizing the difficulties in their manufacture in Europe, it is not strange that the troubles increase when attempts are made to transplant such industries into a new country, where the practical rules applicable in the old locality are vitiated by new sets of conditions, such as atmosphere, temperature, flavors of milk, and other factors. So great have been these troubles that there is a belief that the American product can not be made equal to the imported. It is said that the difference in the food which the cows eat produces a differently flavored milk, thus making domestic cheeses unlike those imported. Whether this be true or not, it is certain that little success has been reached by American makers in trying to reproduce the higher, more delicate grades of European soft cheese. When they have succeeded it has been by importing their help from Europe, and in these cases the makers have carefully preserved their methods as trade secrets. Even in the successful factories many failures occur. Little attempt has been made, apparently, to overcome the new difficulties arising in the new conditions. As a result the home product has commanded an inferior price and is less esteemed than the imported cheese. For this reason the American makers have disguised their goods by French labels and have not tried to make a market for an American product.

The market varieties show great irregularities. Complaint is constantly made by the dealer and consumer as well that common brands of some of the soft cheeses are utterly unreliable. In the purchase of a cheese, except by an expert, it is little more than a lottery whether it will be mostly sour curd or might be eaten through a straw. It is clear, then, that although there is a good market for uniform and reliable goods, radical changes must be made in the methods of production before these soft cheeses will obtain the large place in the American market which their real merit deserves. For the American dairyman the development of this almost new industry well deserves consideration. It is true that more difficulties are involved in the manufacture of the soft than of the hard cheeses, but the returns are correspondingly greater and quicker. Experience, however, in other lines of dairy work shows that thorough scientific study of the conditions, the problems, and the results sought is usually rewarded by the development of successful practical methods of controlling the entire process. The soft cheeses will be shown to be no exception to this rule.

PRESENT MARKET CONDITIONS OF CAMEMBERT CHEESE.

There is good evidence that more than one type of cheese is placed upon our markets under the name of Camembert. All of them have sufficient similarities in texture and appearance to lead to classing them together, but in flavor and odor they show marked differences. Camembert cheeses secured from different regions show much variation. The study of the brands offered for sale in several cities emphasizes an entire lack of uniformity among them. The stage of ripening makes a marked difference in their appearance. One can find upon the same counter cheeses in which ripening has barely become distinguishable mixed with those in every stage of fitness and unfitness for use, even to those which are absolutely putrid, and all are likely to be sold as in prime condition for the table. Such cheeses on the surface may be whitish or grayish in color, or yellowish to reddish, and may be dry or sticky with the accumulation of bacterial growths. They may be practically odorless, or at least inoffensive to smell, or they may emit very objectionable odors. These differences are not due wholly to the degree of ripeness, for cheeses with very different appearance are often found of the same texture and flavor within. Moreover, cheeses with almost identical surface appearance often differ decidedly in texture and flavor. The external differences, we have learned, are due chiefly to the different kinds of microorganisms that grow on the outside of the cheese, some of which are quite unnecessary to the production of the desired ripening. Consultation with dealers shows that there is no accepted ideal among them for Camembert cheese; they disagree constantly on such matters. There also appears to be confusion in many quarters between the types known as Camembert, Brie, and Isigny. This is probably due to the fact that the imported Brie is ripened in very nearly the same way as Camembert, differing only in size and shape and details of making, while the type we have discussed as American Brie, which includes the cheeses sold as Isigny, is very different in its appearance and ripening process, as well as texture and flavor. It has been shown that certain makers use these names as practically interchangeable—that is, regard them as the same general type of cheese molded at different sizes and marketable at different degrees of ripeness, and sometimes the same cheese exactly is sent to market bearing different labels.

THE TRUE CAMEMBERT TYPE.

The true Camembert type of cheese is that imported from France. These are shaped so that they fit wooden boxes about $4\frac{1}{2}$ inches in diameter and $1\frac{1}{2}$ inches thick. Upon the removal of their wrappings, the cheeses usually have a rather firm rind about one-eighth of an inch thick composed of interlaced fungous threads supporting dried cheese. Within, the ripe cheese should be a yellowish cream color, of

a waxy or creamy texture, often almost liquid in age, and with a distinctly characteristic flavor that is often not present in some American types, even though they are labeled Camembert.

REASONS FOR SELECTING CAMEMBERT CHEESE.

Camembert cheese was selected as the first type of soft cheese to be studied, for several reasons. It is one of the most delicate and expensive of the soft cheeses, selling on the market usually for 40 cents a pound. It has been successfully produced by but one large factory in our Eastern States. A few other factories have made cheese called "Camembert," but their product has not made for itself a place in our market in competition with the imported varieties. The marketable period of this cheese is so short that the domestic brand should have a great advantage over the imported.¹ The shortness of the ripening period—four to five weeks—together with the high price of the cheese, insures a good return upon the investment and commends its manufacture to the dairyman located too far from the city to sell his milk as milk. Camembert cheese is already sufficiently well known in this country to insure the ready sale of any brand which shows itself to be always reasonably reliable. Considering the lack of uniform quality in the Camembert cheeses seen on sale in half a dozen of the large cities of the United States, the wonder is not at the smallness of the demand, but that the people will continue to buy it at all. Inquiry shows that many people are fond of the cheese, but never buy it, because they can not depend upon the product. Dealers do not like to handle it, for the same reason. The fact that local demand compels grocers in cities, often against their will, to handle such cheeses is evidence that a really good and reliable Camembert cheese would make for itself a large market. It is readily seen, therefore, that the making of this cheese offers good possibilities of being a profitable industry. The demand could be more suitably met by a large number of dairies or factories, each to supply a limited territory, rather than that an enormous quantity should be produced by a few large concerns. That it requires special study to overcome the difficulties of its production before it can be made by the general dairyman is also evident. For these reasons Camembert cheese seemed to offer a most useful problem.

EUROPEAN LITERATURE CONSULTED.

When we started the work it was impossible to secure at once a cheese maker who was familiar with the factory manipulation in the manufacture of these cheeses. We were, therefore, obliged to work from the vague and inadequate descriptions of the details of making them published in European journals. Practically no detailed account of the practice of the best factories was to be found, while the few scientific papers available scarcely touched the practical prob-

lems. Our problem was to imitate a market type without any personal knowledge of how it was produced. The most extended scientific work that had been published was that of Epstein,^a who made a somewhat careful study of the bacteria and molds found in a series of ripe Camembert cheeses and endeavored to determine which were the agents of ripening. The conclusion reached was that the ripening of Camembert cheese is produced by the agency of bacteria alone, although he also concluded that the ripening of Brie cheese, which is almost identical with Camembert, is aided by a mold.

In opposition to this there have been published the results of the work of Roger,^b who also studied the organisms concerned in the manufacture of Camembert. He reached the conclusion that ripening is produced by the combined agency of a mold and at least two different species of bacteria. Roger's work has the merit of having been practically applied to the manufacture of Camembert cheese, with results which he claims have been very satisfactory. But, on the other hand, Roger has given the public no evidence of the work he has done to reach his conclusions. He has preferred to develop the practical side of his studies as a trade secret, and has, therefore, in his published articles withheld all details of his experiments and descriptions of his molds and bacteria. Consequently the published account of his work is less useful than that of Epstein. Neither worker has given sufficient data to demonstrate his claims or practical methods of cheese making.

The fact that the conclusions of Epstein so totally disagreed with those of Roger suggested that the subject at all events demanded further and more thorough investigation. Moreover, it will be seen in the following pages that our own results, in a large measure, differ from those of both of these investigators, for we have been able to produce Camembert cheese, typical both in flavor and in texture, by a method involving organisms essentially different from those claimed by Epstein or Roger as the cause of ripening. It is scarcely possible that the details of either set of experiments can be all mistakes. The fact that three series of studies upon the same subject have reached three quite different results indicates one of two things: Either the cheeses used in the three series mentioned were of really dissimilar types, though under the same name, or a very similar final product can be produced by different agents. Possibly both of these explanations are needed to account for the discrepancies. Certain of our experiments have yielded information which leads to the belief that each of the three lines of experiment has brought out part of the truth. These results will be discussed in detail later.

^a Archiv f. Hyg., Bd. 43, pp. 1-20; Bd. 45, pp. 354-376.

^b Sep. pub. Soc. Fran. d'Encore, l'Ind. Laitière, 1902, and Revue Hebdomadaire, 11, pp. 327-343.

OUTLINE OF OUR METHOD OF PROCEDURE.

The first problems which we undertook to study were scientific rather than purely practical. The reasons for this were two. First, we were unable at the beginning of our work to secure a cheesemaker familiar with the factory methods of making and curing this type of cheese. Second, it was not our purpose merely to imitate the methods in use in producing this cheese in France. This would have been hardly worth while unless we could obtain a thorough understanding of all the principles involved. It was desirable, therefore, at the outset to conduct a series of experiments which would bear directly upon the determination of these principles, and this could be best done by making a few cheeses under controlled conditions. In this way we reached conclusions upon the problems involved which stood the test of practical experiment and which led quickly to successful results when cheese making was actually begun.

After securing the services of Mr. Issajeff we began the application of our scientific studies to the practical question of cheese ripening. No description of the practical method of making and caring for these cheeses will be given in this introductory paper. These will be given in a later bulletin to follow shortly. It will be understood, however, that the manufacture of Camembert cheeses is being now actually carried on at the Storrs Experiment Station, and that the scientific results given here have been actually applied to the process of manufacture.

RIPENING OF CAMEMBERT CHEESE.

A brief outline of the ripening of Camembert cheese is as follows: The rennet curd is first ladled into forms, filling them up to a depth of about 5 inches, and is allowed to stand for several hours for draining. During this time the curd settles until it reaches a thickness of about 2 inches, when the cheeses are turned and allowed to stand in the forms. During the next twenty-four hours the curd settles still further, reaching a thickness of $1\frac{1}{2}$ inches. The first change affecting the ripening is the souring of the curd, which begins while the cheese is in the forms. In the course of two days the curd has become hard and sour. The cheeses are then removed to the ripening cellar. After a few days in the cellar the molds begin to grow upon their surface. From this time until the end of the ripening period there is little visible external change in the cheese, except in the luxuriant growth of molds and in the fact that during the later stages of the ripening there commonly appears upon the surface of the cheese a brownish-red growth, which is likely to be moist and slimy. This brownish-red growth has been regarded as a necessary factor in the ripening of cheese, but whether it has any necessary connection with it we are as yet uncertain. During the ripening the cheeses at first

become somewhat hard and resistant when pressed with the finger. Later they soften noticeably, and when they approach ripeness they are quite soft and yield readily to the pressure of the finger. The ripeness is determined chiefly by the softness to the touch and is easily told by experience.

The ripening changes are studied by cutting sections of the cheese at various stages. The photographs (see plate 2) show such stages of ripening, of which a brief epitome is as follows:

After about two weeks the acidity of the curd begins to be noticeably less, especially at the surface, and as the ripening progresses the acidity in time disappears so far as indicated by the test with litmus paper. Meantime a change in the texture of the curd is evident to the eye. Beginning at the outside, there appears a change of the hard curd into a somewhat softer, waxy material. This layer of waxy cheese, beginning at the surface, slowly extends toward the center and in the course of four to five weeks should reach the center. In half-ripened cheeses there will be found a layer of softened consistency on the outside, with a central mass of acid curd within, which has not yet been affected by the ripening agents. When the cheese is completely ripened the softening extends to the center, and the whole cheese, from the outside to the middle, has assumed a consistency of moderately soft butter. When in prime condition the cheese is soft enough to spread upon bread or crackers, but not soft enough to run. An over-ripened cheese, however, becomes still softer until in time the whole interior of the cheese below the rind is converted into a nearly liquid consistency, which will run out of the cheese readily if the rind is broken. On the other hand, an under-ripened cheese will show more or less of the sour curd in the center which has not been affected by the softening agents. The cheeses purchased in the market are very frequently in one of these two conditions, either overripe or underripe. (See plates 1 and 2.)

During the ripening process there appears a peculiar flavor which is characteristic of this type of cheese. This flavor is sometimes not noticeable until the cheese is nearly ripe, so that a cheese which is two-thirds ripened may lack the flavor in question. The final result is a cheese with a firm, moldy rind, and with the contents uniformly soft to the center, and possessing a characteristic, piquant flavor which is found in this type of cheese only.

The problems to be determined were the causes of the phenomena of ripening, and these are manifestly three.

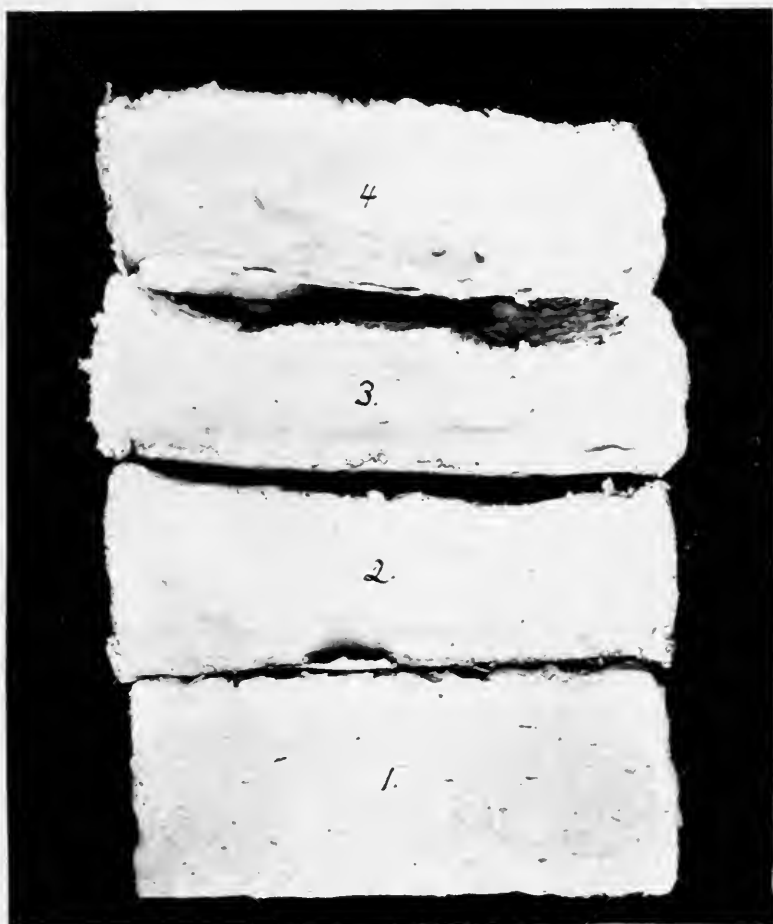
- (1) The cause of the original souring of the curd.
- (2) The cause of the decrease in the acid and the gradual softening of the curd.
- (3) The development of the flavors.



FIG. 1.—A BOARD OF CAMEMBERT CHEESES.



FIG. 2.—AN IMPROPERLY RIPENED CAMEMBERT CHEESE.
The outer portion is liquefied, while the center is hard, sour curd.



A SERIES OF CAMEMBERT CHEESES.

Fig. 1, unripened cheese; fig. 2, half-ripened cheese with well-developed moldy rind; fig. 3, cheese two-thirds ripened but with central mass of hard curd showing some gas holes; fig. 4, cheese nearly ripe and so soft that the upper edge moved because of its weight during the exposure.

COMPENDIUM OF OUR SCIENTIFIC INVESTIGATIONS.

Our work has been developed along three scientific lines; the results of each line are summarized below. More detailed accounts of these studies will follow in separate papers.

MYCOLOGY.

The constant appearance of mold in or upon soft cheeses such as Roquefort, Camembert, and Brie has been referred to already. The works of Epstein and Roger, already discussed, give two views of their relation to the production of cheese. Epstein believes the mold entirely unnecessary in the production of Camembert, but notes its presence and important function in the ripening of Brie. Roger, on the contrary, believes the mold to be really essential in the ripening of Camembert. Other investigations published record the constant appearance of mold upon Brie, but give little or no information with reference to Camembert. Popular descriptions of Camembert cheese factories, however, describe the constant presence of a special mold in the ripening cellars. The references to molds in the literature of the subject and their constant presence upon the cheeses fixed for us a series of questions: What molds are associated with Camembert cheese as found in the market? Which, if any, of these are essential to its proper ripening? Exactly what changes in the ripening process result from fungous activity? What molds are deleterious? And what is their action?

With these questions in mind we first made a cultural study of the flora of the Camembert cheeses found in the American market. In this about twenty molds were soon found, isolated in pure cultures, and described. A more careful study of our cultures with a comparative examination of the surfaces of the different kinds of cheese showed that only a few of these molds were really common, while but two of them were always present.

Having the organisms in pure cultures, we next undertook to determine what relation, if any, each might bear to the ripening process. Since it is practically impossible to make cheeses entirely free from other molds, or bacteria, or both, without changing their chemical nature, some controlled means had to be devised to study the various agents of ripening and the steps of the process. We found it necessary to limit this comparative study to the effects of a small group of molds. These were grown in pure culture under known conditions upon milk, casein, curd, cheeses, and special media, all so devised as to determine separately different phases of the physiological action of the molds. For this study we used (1) the one we shall call the "Camembert mold" (culture No. 128); (2)

the related species isolated from Roquefort cheese, which we will call the "Roquefort mold;" (3) one species of *Mucor*; (4) *Oidium lactis*, and sometimes other species of the same genus, *Penicillium*. In some studies the list has been extended to a dozen species in each experiment, because with the larger numbers comparison of characters gives a better judgment of the real nature of the processes studied.

The souring of the curd as a consequence of the presence of lactic bacteria has already been described as the first change after the cheese is made; also the fact that in Camembert cheese the lactic acid so produced later largely disappears, so that when fully ripe such a cheese commonly has an alkaline reaction to litmus. This disappearance of acid, together with the well-known ability of many molds to reduce acidity, has been regarded as the main, if not the only, function of the mold in ripening cheese. This view has been widely quoted. Comparative cultures of a large number of species show that a very large proportion of the common molds are able to neutralize, if not decompose, lactic acid, but they do this in different degrees and at very different rates. The Camembert mold increases the acidity of the medium during its first few days of growth, then changes and reduces acidity for the remainder of the period of activity. Some other forms reduce acidity from the first and do it much more rapidly than this one. If this were the only function of the mold in cheese ripening, many other species should be equally valuable, or by working more rapidly would probably be far more effective. This part of the ripening then might be accomplished by any one of a large number of forms.

We then turned our attention to determining whether any or all of these fungi acting in pure cultures possessed the power to change the hard curd to the semiliquid or viscous condition of the ripened Camembert cheese. A long series of cultures upon sterilized milk, milk agar, and sterilized curd were prepared. Careful bacterial determinations were made to show that the cultures were pure. From these the following facts appeared: Sterile milk is slowly but almost completely digested by nearly every species of fungus tried. Flakes of curd in milk agar plates disappear as a result of the action of the fungi selected for this experiment. Masses of curd put in flasks and sterilized in the autoclave until they seemed almost the texture of rubber became nearly completely soluble in water after four to six weeks' action of either the Camembert or the Roquefort mold. Experimental cheeses made from time to time, with the addition of large quantities of "lactic starter" to exclude other bacteria, were inoculated with this mold and carefully kept pure in bell jars. Under favorable conditions such cheeses assumed the texture of ripe Camembert cheese in from three to five weeks. Repeated analyses have shown that this is approximately the same kind of digestion as is found in the ordinary

Camembert cheese. These pure-culture experiments have thus shown that this species of mold possesses the ability to change the texture of curd to the texture of ripe cheese in the period of time recorded by the makers of such cheese as necessary for the ripening of Camembert.

How, then, is such a result accomplished? Johan-Olsen in describing the Swedish "Gammelest" declares that "he who eats Gammelest eats truly more mold than cheese." In other words, he believes that in its ripening process the changes are due to the complete penetration of the cheese by fungous threads which act directly to change its character. Gammelest would then be fungus flavored with cheese! But cultural studies and careful microscopic examination of hundreds of sections from a number of different Camembert cheeses show that our problem is very different. In Camembert cheese the mold forms a felted mass of hyphæ upon the surface and penetrates, perhaps, one-sixteenth of an inch into the curd. It never reaches even one-third of the distance to the center of the cheese, while its spores are borne only upon the surface. This, together with a very thin outer layer of curd, constitutes the rind of the cheese.

Further, our experiments referred to above show also that on sterile milk the mold forms colonies floating upon the surface only, while a mass of curd in the bottom of the tube, fully 2 inches away from the nearest fungous thread, may still continue to be digested. It is clearly impossible to attribute these marked digestive effects at such distances to the direct action of the fungous threads upon the medium. From similarity to other known processes, the presumption arises that these are the result of the secretion of enzymes by the mold.

To test the validity of this hypothesis, a set of cultures were grown for a long time on Raulin's fluid, then examined by the chemist. The presence of an enzyme capable of digesting proteid was satisfactorily demonstrated. We have, therefore, shown by pure-culture methods that the Camembert mold (*Penicillium candidum*?) is not only capable of changing the acidity of the curd, but is able also to cause such changes of the curd as will account for the texture of the ripe cheese, and that this result is due to the secretion of an enzyme.

A cheese ripened by this mold alone is white, soft, creamy, and entirely palatable, but is wanting in color and completely lacks the peculiar flavor for which Camembert cheese is sought in the market. After repeated tests had shown the same result, we began to seek for some other organism capable of producing the desired flavor. The discovery of this flavor in certain experimental cheeses at this time was followed by their immediate microscopic examination, which showed the presence of the second of the two fungi originally found on Camembert cheese. This mold, the well known and universally distributed *Oidium* (or *Oospora*) *lactis* had been discarded from much of our work on account of some failures and objectionable

results. We now found that the inoculation of this organism upon cheeses partially ripe and lacking flavor would lead to the production of the flavor distinctly in a very few days. Although from its habits of growth its development upon cheese is nearly always accompanied by a rapid multiplication of bacteria, this seemed good circumstantial evidence that *Oidium lactis* has something to do with the flavor of Camembert cheese. Additional evidence is found in the fact that the examination of properly flavored ripe cheese of our own make and from the market has never failed to show its presence, and it has never been shown to be present upon ripe cheeses without the flavor being present also. The great difficulty surrounding complete proof of the agency of a particular organism in producing flavor lies in the fact that the flavors do not begin to appear until the acidity of the curd is much reduced and the digestion attributed in our work to the *Penicillium* has advanced considerably. Flavors, the chemists tell us, are associated with the "end products of digestion." When ripening has reached such a stage as to permit flavor formation, the growth of *Oidium* upon the surface of a cheese usually becomes complicated by the development of surface bacteria, which becomes possible at about that time on account of the reduction of the acidity. A final conclusion as to whether or not *Oidium lactis* alone produces the flavor will depend upon an exhaustive test of those bacteria so constantly associated with it.

The bacteriologists, as will be seen later, have shown that few bacteria, except lactic species, are found within the cheese, and none of them seem able to produce flavor. The production of flavor by bacterial action would then depend entirely upon such bacteria as might grow upon the surface of the cheese. In addition to the evidences already mentioned, it is found that a cheese entirely covered by a good growth of the Camembert mold evaporates water rapidly and develops a hard, dry rind, so dry as to obstruct the entrance of bacteria from without. In certain of such cheeses, into which *Oidium* was inoculated at the time of making, the characteristic flavors finally appeared, without the association of the reddish slimy surface so commonly seen. Further, many cheeses made and ripened entirely without *Oidium lactis* have in their later stages become covered with bacteria, which produced the surface appearances so often described, but failed entirely to develop the typical flavor. In the light of the bacteriological proof that the interior of the cheese is practically a pure culture of lactic organisms, the production in some cases of both the flavor and texture of properly ripened Camembert cheese without a rich surface growth of bacteria is very good circumstantial evidence that *Oidium* has some function in producing the flavor.

A cheese inoculated with Camembert *Penicillium* will not begin to show delicate white threads of mold for about three days. The mold

develops rapidly from that time until, by the tenth day (sometimes by the seventh or eighth), the cheese is usually covered entirely by a pure white, cottony mass of threads forming a layer possibly one-eighth of an inch deep. With the ripening of the spores or conidia the color gradually changes to a greenish gray. This change is completed during the third week usually, and no growth seems to take place afterwards. During the later stages of mold growth large drops of water are excreted by the mold and evaporate from the surface. The mold, therefore, has a rather definite period and course of development. During that time it seems to be so thoroughly adapted to thrive upon cheese as to exclude almost every other form, but after its cycle of development is complete it may be followed by other species which, if present before, are held in check by the more vigorous species.

One more phase of the mold problem perhaps belongs in this preliminary paper. Efforts have been made to find whether it is possible to substitute other varieties or species of the same genus of fungi for the one we have been using. For such studies the mold of Roquefort cheese has been carried as a check upon our work in numerous experiments. One other variety of *Penicillium*, differing only in that it never changes color, but remains pure white, has been tested. Cheeses have been made with these three and several other related species. The Roquefort *Penicillium* grows strongly and rapidly upon cheese, but its presence always causes a bitter taste, which remains pronounced during the period of four or five weeks necessary for the ripening of Camembert. So strong is this effect that the presence of a colony of this mold less than an inch in diameter may often be detected by the taste of the cheese 2 inches away. The pure white *Penicillium* in its ordinary reactions to culture media seems to be identical with the Camembert mold, but when tested upon over one hundred cheeses produced a texture so entirely different from it as to make the product entirely worthless. It seems most surprising that two forms so closely related in structure and in every reaction studied should produce such different results in cheese ripening. Several other forms have been tried. Some produce pigments which discolor the cheese; some produce bad flavors. A set of four species, although allowed to grow for a period of six weeks, produced no softening of the curd. In two of these cheeses especially it was found that the curd was still sour and little changed less than one-fourth of an inch below the colonies of the fungus. The four cheeses used in this experiment belonged to a set of twenty, sixteen of which ripened readily in the ordinary way. Sets of cheeses made from the same milk and treated alike ripened quite uniformly, as a rule. Of this set, 16 ripened in the usual manner when acted upon by Camembert *Penicillium*. Four inoculated with other *Penicillia* failed to

soften. Such a result shows that neither the molds used nor the bacteria and enzymes otherwise present were capable of producing the texture of Camembert in four cheeses of a series, the remainder of which were readily ripened normally.

- BACTERIOLOGY.

The universal presence of bacteria in all dairy products suggests of course that they may play an important part in the ripening of cheese. In the various scientific accounts of Camembert cheese bacteria are always mentioned, and both Epstein and Roger attributed to their action a considerable part of the ripening and flavor production. Our own preliminary studies of the market cheeses always showed the presence of bacteria in great number and in considerable variety. It was manifest that most of these were purely incidental organisms not contributing at all to the ripening. In the study of these bacteria the following questions have been kept in mind: Which kinds of bacteria are always found and which are only occasionally present? Which kinds of bacteria are present in fresh cheese? Which kinds of bacteria grow during the ripening? Do any of these bacteria produce the Camembert flavor? Do the bacteria contribute to the chemical changes that occur during the ripening? Part of these questions we have already answered, but part of them require further study.

We first made a bacteriological study of a considerable number of ripened cheeses, isolating all species of bacteria that could be found. Except that lactic bacteria were always found, this work gave no significant results. We were somewhat surprised to find that the group of bacteria that digest proteids—the liquefiers—were commonly entirely absent. Inasmuch as the cheese is so evidently a digested product, we had anticipated finding them in large numbers. This absence in large numbers suggested that the digestive agent must be looked for elsewhere than in bacterial action.

Our search for a flavor-producing bacterium has hitherto been equally unsuccessful. Epstein states that by inoculating into a casein solution one of the bacteria he isolated from Camembert cheese he obtained a typical flavor. We have been unable to find such a bacterium. We have carefully studied the action upon milk of the organisms isolated from cheeses in the hope of finding a flavor-producing bacterium, but have thus far been unable to find one. We have, however, found bacteria that produce flavors that remind us of the American Brie, and of other flavors associated with some samples of cheese, but none that gave the typical Camembert flavor. We are at present inclined to think that this flavor must be sought in some other line, as has been shown in the previous pages.

The study of the growth of bacteria in the cheese during the

ripening is very interesting and significant. We have studied this problem in cheeses made with and without a lactic starter. The cheeses made with a lactic starter are more uniform in ripening. Experience has shown that we can with greater certainty obtain a first-class cheese if we use such a starter. For this reason the study of the bacteria in such cheeses is especially significant. The results are very simple, for they are an exact repetition of what occurs in souring milk, as has been already shown.^a At the outset there is commonly a small variety of bacteria present, which develop for a short time, but in a few hours the lactic bacteria get the upper hand and all other species practically disappear. After about two days the cheeses contain a practically pure culture of lactic bacteria. These increase in numbers until they are about 900,000,000 per cubic centimeter, and then remain at about this number during the ripening, somewhat falling off toward the end. In these cheeses there is no growth of liquefying bacteria to which might be attributed such digesting action. There are commonly a few of these at the start, but they never multiply so that they become abundant enough to lead to the supposition that they are likely to play any part in the ripening. Moreover, as mentioned above, the ripening of these cheeses proceeds from the surface inward, a fact that indicates that the ripening agents are chiefly or wholly on the surface.

These facts are rendered more significant by the bacteriological study of one set of 20 cheeses that were made without lactic starter. In these cheeses the lactic bacteria never obtained such a complete ascendancy over the other species as where a starter was used. While they became very abundant we found that certain liquefying bacteria multiplied and remained in considerable number to the end of the ripening. The presence of large numbers of such enzyme-producing bacteria during the ripening suggests that they may have contributed to the process. It was especially significant to find (1) that this cheese ripened in the center before it did on the outer edge, as would be expected if the bacterial enzymes aided in the ripening, and (2) that the final product was in flavor and texture not very different from the more typically ripened cheeses. This would seem to suggest that while the normal ripening is not due to the bacteria or enzymes in the body of the cheese, but to the organisms on the surface, under some circumstances the former may materially contribute to the process, and while producing a somewhat abnormal ripening will give in the end a similar result.

From the facts thus outlined we have reached the conclusion that the bacteria in the body of the cheese are in normally ripening cheeses concerned only in the souring of the curd as preparatory to the later changes. This leads naturally to the study of the organisms present

^a Conn and Esten, Rept. Storrs Sta. 1901-2.

in the outer layers. This rind contains a variety of molds and bacteria. The presence of certain molds in the rind of every Camembert cheese examined suggested from the first that they must be important agents in the ripening process. This has been demonstrated in the preceding section, but this rind also under most circumstances contains many bacteria. Our study of these bacteria and their actions is not yet complete. We have as yet no good evidence that their action is necessary to the production of a first-class product. That they occasionally modify the final cheese is quite certain, and we are also convinced that they play an important part in the ripening of the type we have called the "American Brie." Whether they have any influence on the production of the typical Camembert flavor can only be determined by subsequent experiments.^a

It should finally be stated that the surface of the ripening cheeses very frequently becomes covered by an abundant growth of yeast, a phenomenon which the makers call "sweating." At present we have no grounds for believing that this has any influence upon the ripening unless it be to check in a slight degree the drying of the surface of the cheese.

CHEMISTRY.

The chemical composition of a normal Camembert cheese is quite well known, considerable work in this line having been done. This work, however, is not of much help in studying the changes that take place during the ripening process and makes it necessary to go over the same ground that has been covered in the work done on Cheddar cheese.

The great difference in the making and ripening of Cheddar and Camembert cheese soon made it apparent that an entirely different set of factors were at work and that the chemical side of the investigation opened a field which would require considerable time to complete.

We have undertaken (1) to follow the chemical changes which render the insoluble curd of a newly-made cheese into soluble forms

^a Since the above was put in type we have received from France a set of cheeses selected and forwarded by M. Georges Roger, accompanied by a letter giving data as to age and condition of ripeness. Studies from the surface of these cheeses have shown the presence of the same *Penicillium* we are using, of *Oidium lactis*, and of the same species of bacteria which appear on our cheeses and contamination with the same other molds we have met. These bacteria on the older cheeses formed reddish-brown slime, almost entirely covering the cheese. Systematic tests of these red-slime producing bacteria are being made to ascertain what effect they may really have upon the ripening of the cheese. Cultures made from the interior of the cheese showed practically pure cultures of lactic organisms, as in our own cheese. These results suggest that we have the same organisms as M. Roger, though under different names.

found in a cheese ready for consumption; (2) to isolate and study the enzyme or enzymes which cause these changes; (3) to investigate the changes which concern the production of the peculiar flavor which is characteristic of Camembert cheese; and (4) to show the relation which each of the constituents of a newly-made cheese bears to the ripening process.

Up to the present time all our attention has been given to work upon the nitrogen constituents of the cheese. This was because of an early belief, confirmed later to some extent, that the fat plays a secondary part in the ripening and in the development of the flavor in Camembert cheese.

The market product was first studied to establish a standard. This was secured from the analyses of a number of imported cheeses. Our cheeses compare favorably with these, yet we hope to obtain improvement by a slight modification in our methods of making and in the handling of the cheeses in the ripening cellar—that is, acidity, humidity, temperature, and washing the cheeses.

TABLE 1.—*Chemical changes in the ripening of Camembert cheese.*

Laboratory No.	Age.	Total nitrogen.	Nitrogen as mono-lactate.	Nitrogen as water-soluble.	Nitrogen as amids.	Nitrogen as ammonia.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
25a	1	2.73	0.40	0.32	0.23	0.00
25b	3	2.73	.41	.41	.21	.00
26a	5	2.81	.39	.45	.21	.00
25c	6	2.73	.41	.54	.27	.00
26b	7	2.81	.39	.52	.27	.00
27a	8	2.92	.43	.53	.26	.00
26c	10	2.81	.67	.73	.38	.00
27b	11	2.92	.62	.75	.61	.00
28a	12	2.90	.61	.69	.53	.00
27c	14	2.92	.57	1.65	.48	.00
28b	18	2.90	.27	1.76	.48	.01
29a	19	2.65	.34	1.59	.43	.02
28c	20	2.90	.17	1.85	.42	.06
a 29b	21	2.65	.13	1.79	.48	.06
14	28	2.61	(b)	2.09	.46	.21

^a This series of cheeses "went bad" with bacteria after this sample was taken. For comparison the analysis of another cheese, No. 14, is given.

^b Not determined.

The first change is the precipitation of the casein of the milk by rennet. This precipitate or coagulum carries down with it most of the fat and some of the milk sugar. The sugar is changed in a few days by bacteria into lactic acid, rendering the curd distinctly acid in reaction to litmus. The fat undergoes some slight changes, but the precipitated casein undergoes a very marked modification.

Practically no change takes place in the cheese except the development of acid during the first twelve days. Then the curd begins to

soften and is gradually changed from an insoluble lump into a soft, creamy mass almost entirely soluble in water. This change starts at the outside and progresses inward toward the center until the whole mass has been acted upon.

This change in the curd is probably due to one or more enzymes produced by the molds growing on the cheese. These enzymes begin their activity at about the fruiting time of the molds—about the twelfth day. They have not been separated as yet, but the evidence at hand seems to indicate the presence of both tryptic and peptic-like enzymes.

Some idea of the changes that take place can be obtained from the table on the preceding page.

GENERAL CONCLUSIONS.

Although the results of these lines of work are still incomplete, some conclusions have been reached which bear directly upon the practical problems. These conclusions have been put to the test of constant use since the establishment of our ripening cellar, and have brought a much better understanding of the problems involved than was before available.

It has been conclusively shown that the making of Camembert cheese is not dependent upon unique conditions obtainable only in very restricted localities, but rather upon securing the proper cultures and conditions, which are possible almost anywhere. Cheeses made at this station have been compared with the best imported goods obtainable in America, and pronounced practically identical, not only by members of the force, but by importers and connoisseurs who have eaten this type abroad. These cheeses are in no way inferior in texture or flavor to the best market article. They have been ripened by inoculation with pure cultures and have been watched constantly and tested by the bacteriologists, the chemist, and the mycologist at every stage of their ripening. The element of chance is thus excluded from the result. The organic agents involved are known. The difficulties encountered in the attempts to establish this brand of cheese-making in the past have, therefore, been due to insufficient knowledge of the molds and bacteria involved in the process, rather than to failure in obtaining any peculiar conditions or the proper milk.

Our practical work also proves that it will be possible to control the ripening to such an extent as to produce a more uniform product. It has been the practice of the makers in the past to provide suitable conditions and then, as one has put it, let "nature do the ripening." As a consequence of this "hit or miss" way of doing things, some cheeses are inoculated with the proper cultures from the first, some bear one organism and not the other necessary, while wrong

species of bacteria and mold very commonly grow in or upon the cheeses, so that the final results are very uncertain. This accounts in a large measure for the variation in appearance, texture, and flavor of such cheeses, and is apparently responsible for the differences between the imported and American-made types.

CONTROL OF THE BACTERIA AND MOLDS.

It became evident very early that uniformity depends upon the controlling of the growth of bacteria and molds from the time the cheese is made until the close of the ripening. This pointed to inoculation as the best means of reaching the desired result. Experience has justified this conclusion at every step. The use of lactic starters in butter-making had already established a simple means of controlling the development of bacteria. The control of the molds was a more difficult problem, inasmuch as there are at least two different molds, and to obtain the desired result depended upon keeping the proper balance between these two organisms growing upon the same surface, but having different functions. We have learned that by varying the conditions and growth of the *Penicillium* we can, to a large extent, control the development of the other mold. *Oidium* will not grow profusely upon a cheese already covered with the white mold, and by developing a luxuriant growth of the latter we can hold the former largely in check. Cheeses in which the *Oidium* has not developed abundantly are either mild in flavor or lacking entirely in the typical Camembert flavor. We have succeeded in producing cheeses perfectly ripened so far as texture is concerned, but flavorless, others with the flavor distinctly developed but mild, and others again with a strongly developed Camembert flavor. Our experiments thus far seem to show that by controlling the growth of these two molds we can control both ripening and flavor production, although, as above suggested, we have not yet absolutely excluded the possibility that bacteria may play some part in the process of flavor production.

The important practical problem, then, appears to be to devise methods of treatment that will enable the cheesemaker to control the growth of microorganisms, and primarily the lactic bacteria and two species of molds. The control of the first process of souring of the curd is very easy. It is only necessary to apply here the method now so widely used in cream ripening, namely, the inoculation of the milk with lactic starters. These starters, if placed in fresh milk, insure a proper souring with perfect uniformity.

The control of mold growth is a more difficult matter, because of the great likelihood that the cheeses in handling will become inoculated on the surface with other than the desired organisms. The

solution of the problem, however, appears to be found in proper attention to three factors.

(1) The inoculation of the cheese at the proper stage with a comparatively large quantity of the spores of the desired organisms. At just what stage the inoculation should be made and in what way we are not at present prepared to say. The question of direct inoculation of cheese with two molds as a means of controlling ripening is an entirely new one in the discussion of this cheese problem. The practice of the factories has been to allow the cheese to develop the proper mold after entering the ripening room. But there seems to be a good reason for a change in this particular. Milk as it reaches the factory already contains the germinating spores of many species of fungi. Some of these forms develop even more rapidly than the ones essential to our purpose. The proper mold has never been found by us in thousands of cultures of milk as it comes from the barn, while undesirable species are very common. If the *Penicillium* essential to cheese ripening is to take and maintain the ascendancy in the ripening process it is imperative that it should begin to grow as soon as the cheese is made. Although further experience is necessary to determine the best time and manner of the introduction of the molds, we are convinced that their early introduction gives advantages more than compensating for the additional labor involved.

(2) The cleanliness of the ripening cellar. The cheeses remain in the ripening cellar from four to five weeks, where the conditions are kept ideal for mold growth. If the walls, shelves, or floors are allowed to become covered with a growth of miscellaneous molds, their spores are sure to reach the cheeses and are then liable to produce trouble. The remedy for this is cleanliness, and special care should be taken to prevent the growth of molds in the ripening room.

(3) The treatment of the cheese in the cellar. We have learned that variations in moisture and temperature of the ripening cellar, and different methods of handling the cheeses, all greatly influence the growth of the molds and bacteria. A perfectly uniform method of handling is therefore necessary for perfect uniformity in results. Differences in little matters of detail are found in the treatment of cheeses in different factories, and these become the basis of each maker's brand. Some wash their cheeses; others do not. Some turn them more often than others. Some send them to the market in a greener condition than others.

GENERAL SUMMARY.

The conclusions we have drawn at present are as follows:

1. The ripening of Camembert cheese is due to the presence of definite molds and bacteria. It is not merely a matter of manipulation and locality.

2. One mold (*Penicillium candidum*?) produces the principal changes in the curd which gives the texture of the normally ripened cheese. Another (*Oidium lactis*), acting in conjunction with the first, is necessary to produce the flavor.

3. The presence of lactic bacteria (commonly used in the form of a starter) produces the necessary acidity of the curd and prevents further bacterial action within the body of the cheese.

4. No other organisms seem absolutely necessary to produce the texture and flavor of Camembert cheese, though other species of bacteria are always present in or on the cheese.

5. It is possible so to control the process of ripening as to produce such results with reasonable uniformity.

6. It is perfectly practicable to produce first-class Camembert cheese in the United States.

ANOTHER REPORT PROPOSED.

In this introductory paper only the general principles can be outlined, and we hope to follow this paper soon with another which will give in detail the actual methods of making and handling which we have found most successful in producing the best product.

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